

1 WHAT IS CLAIMED IS:

- 2
- 3 1. A method of using a position-velocity table to control a dynamic system, the
4 method comprising the steps of:
5 generating a position variable for the system;
6 determining a velocity command for the system using the position-
7 velocity table, the determining step determining the velocity command
8 based on the position variable;
9 shaping the velocity command in order to generate a shaped
10 velocity command; and
11 controlling the system based on the shaped velocity command.
- 12
- 13 2. A method according to Claim 1, wherein the method controls a component of the
14 dynamic system, the component comprising a head of a data storage device; and
15 wherein the controlling step controls the head to move among
16 various tracks of a data storage medium in the data storage device.
- 17
- 18 3. A method according to Claim 2, wherein the generating step comprises comparing
19 a preset position of the component to a measured position of the component in
20 order to determine the position variable; and
21 wherein the method further comprises the step of performing
22 inverse shaping on the measured position prior to comparing the measured
23 position to the preset position.
- 24
- 25 4. A method according to Claim 3, wherein the shaping step and the inverse shaping
26 step reduce unwanted vibrations resulting from movement of the component.
- 27
- 28 5. A method according to Claim 3, wherein the measured position of the component
29 is determined after the controlling step controls the component; and

1 wherein the measured position of the component is fed back to the
2 determining step following the controlling step.

3

4 6. A method of generating a trajectory for inclusion in a position-velocity table
5 which is used to control a dynamic system, the method comprising the steps of:

6 generating a trajectory for the dynamic system, the trajectory
7 defining system velocity in terms of system position and one or more
8 additional variables;

9 storing the trajectory in a position-velocity table having N (N>2)
10 dimensions; and

11 controlling the dynamic system in accordance with the trajectory
12 stored in the position-velocity table.

13

14 7. A method according to Claim 6, wherein the method controls a component of the
15 dynamic system, the component comprising a head of a data storage device; and
16 wherein the controlling step controls the head to move among
17 various tracks of a data storage medium in the data storage device.

18

19 8. A method according to Claim 7, wherein one of the variables comprises a desired
20 movement distance of the component.

21

22 9. A method according to Claim 7, wherein the trajectory is generated in real-time
23 based on a partial fraction expansion that defines behavior of the dynamic system.

24

25 10. A method of controlling a dynamic system in accordance with a variation in a
26 system variable, the method comprising the steps of:

27 generating a plurality of trajectories defining system velocity in
28 terms of system position, the plurality of trajectories being generated in
29 accordance with at least one system variable;

1 storing the plurality of trajectories in a single position-velocity
2 table;

3 detecting a value of the at least one system variable; and

4 controlling the dynamic system in accordance with both the
5 detected value of the system variable and the trajectories stored in the
6 position-velocity table.

7

8 11. A method according to Claim 10, wherein the position-velocity table comprises a
9 series of trajectories corresponding to various component movement distances;
10 and

11 wherein the controlling step comprises selecting one of the
12 trajectories from the position-velocity table based on the detected value of
13 the system variable and controlling a component of the dynamic system in
14 accordance with the selected trajectory.

15

16 12. A method according to Claim 10, wherein the controlling step comprises
17 generating a function based on the plurality of trajectories and the system
18 variable, determining a single trajectory for the component based on the function,
19 and controlling a component of the dynamic system based on the single trajectory.

20

21 13. A method according to Claim 10, wherein the generating step comprises the steps
22 of:

23 estimating system parameters, the system parameters relating to
24 movement of a component of the dynamic system;

25 determining whether the system parameters have varied from
26 predetermined system parameters;

27 modifying the trajectories based on determined system parameter
28 variations; and

29 storing the modified trajectories in the position-velocity table.

30

- 1 14. A method of generating a trajectory for inclusion in a position-velocity table
2 which is used in controlling a dynamic system, the method comprising the steps
3 of:
4 generating a trajectory for use in the dynamic system;
5 storing the trajectory in the position-velocity table; and
6 controlling the dynamic system in accordance with the trajectory
7 stored in the position-velocity table;
8 wherein the generating step generates the trajectory in accordance
9 with a technique for reducing unwanted vibrations in the dynamic system.
- 10
- 11 15. A method according to Claim 14, wherein the method controls a component of the
12 dynamic system, the component comprising a head of a data storage device; and
13 wherein the controlling step controls the head to move among
14 various tracks of a data storage medium in the data storage device.
- 15
- 16 16. A method according to Claim 15, wherein the technique for reducing unwanted
17 vibrations of the component comprises generating the trajectory by taking into
18 account both a system vibration limiting constraint and a system sensitivity
19 constraint.
- 20
- 21 17. A method according to Claim 16, wherein the system vibration limiting and
22 sensitivity constraints reduce vibration during movement of the component by
23 less than 100%.
- 24
- 25 18. A method according to Claim 15, wherein the technique for reducing unwanted
26 vibrations of the component comprises generating the trajectory by taking into
27 account one or more constraints which are a function of a movement distance of
28 the component.
- 29

- 1 19. A method according to Claim 15, wherein the technique for reducing unwanted
2 vibrations of the component comprises generating the trajectory by taking into
3 account a system vibration limiting constraint only.
4

5 20. A method according to Claim 15, wherein the technique for reducing unwanted
6 vibrations of the component comprises generating the trajectory based on an input
7 which has been shaped in accordance with a predetermined shaping function.
8

9 21. A method according to Claim 20, wherein the input includes both transient
10 portions and a steady state portion; and
11 wherein only the transient portions of the input have been shaped
12 in accordance with the predetermined shaping function.
13

14 22. A method according to Claim 15, wherein the technique for reducing unwanted
15 vibrations of the component comprises generating the trajectory by filtering a
16 predetermined trajectory using filters having zeros which are substantially near
17 poles of the system.
18

19 23. A method according to Claim 15, wherein the technique for reducing unwanted
20 vibrations of the component comprises generating the trajectory by taking into
21 account at least one of constraints relating to system thermal limits, system
22 current limits, and system duty cycle.
23

24 24. A method according to Claim 15, wherein the technique for reducing unwanted
25 movement of the component comprises the steps of:
26 determining whether a trajectory excites greater than a
27 predetermined level of vibrations in the system; and
28 applying input shaping to the trajectory in a case that the trajectory
29 excites greater than the predetermined level of vibrations.
30

- 1 25. A method according to Claim 15, wherein the technique for reducing unwanted
2 vibrations of the component comprises generating the trajectory based on a
3 Posicast input.
- 4
- 5 26. A method according to Claim 15, wherein the technique for reducing unwanted
6 vibrations of the component comprises generating the trajectory based on a
7 symmetric input.
- 8
- 9 27. A method according to Claim 15, wherein the technique for reducing unwanted
10 vibrations of the component comprises generating the trajectory based on a
11 symmetric constraint that varies as a function of at least one of time and
12 component position.
- 13
- 14 28. A method according to Claim 15, wherein the technique for reducing unwanted
15 vibrations of the component comprises generating a trajectory in accordance with
16 a voltage which has been controlled by controlling current.
- 17
- 18 29. A method according to any one of Claims 14 to 28, wherein the generating step
19 comprises:
20 identifying system parameters in real-time; and
21 modifying the trajectory in real-time in accordance with the system
22 parameters identified in the identifying step.
- 23
- 24 30. A data storage device which uses a position-velocity table to control movement of
25 a component of the data storage device, the data storage device comprising:
26 a memory which stores the position-velocity table and computer-
27 executable process steps; and
28 a processor which executes the process steps stored in the memory
29 so as (i) to generate a position variable for the component, (ii) to
30 determine a velocity command for the component using the position-

1 velocity table, the processor determining the velocity command based on
2 the position variable, (iii) to shape the velocity command in order to
3 generate a shaped velocity command, and (iv) to control the component to
4 move based on the shaped velocity command.

5
6 31. A data storage device according to Claim 30, wherein the component comprises a
7 head of the data storage device; and

8 wherein the processor controls the head to move among various
9 tracks of a data recording medium in the data storage device.

10
11 32. A data storage device according to Claim 30, wherein, to generate a position
12 variable for the component, the processor compares a preset position of the
13 component to a measured position of the component; and

14 wherein the processor further performs inverse shaping on the
15 measured position prior to comparing the measured position to the preset
16 position.

17
18 33. A data storage device according to Claim 32, wherein the shaping and inverse
19 shaping performed by the processor reduce unwanted vibrations resulting from
20 movement of the component.

21
22 34. A data storage device according to Claim 32, wherein the processor determines
23 the measured position of the component after controlling the component; and

24 wherein the processor uses a previously-measured position of the
25 component to determine the position variable.

26
27 35. An apparatus which generates a trajectory for inclusion in a position-velocity
28 table that is used in to control a dynamic system, the apparatus comprising:
29 a memory which stores computer-executable process steps and a
30 position-velocity table having N (N>2) dimensions; and

1 a processor which executes the process steps stored in the memory
2 so as (i) to generate a trajectory for the system, the trajectory defining
3 system velocity in terms of system position and one or more additional
4 variables, (ii) to store the trajectory in the position-velocity table, and (iii)
5 to control the system in accordance with the trajectory stored in the
6 position-velocity table.

7

8 36. An apparatus according to Claim 35, wherein the apparatus controls a component
9 of the dynamic system, the component comprising a head of a data storage device;
10 and

11 wherein the processor controls the head to move among various
12 tracks of a data storage medium in the data storage device.

13

14 37. An apparatus according to Claim 36, wherein one of the variables comprises a
15 desired movement distance of the component.

16

17 38. An apparatus according to Claim 36, wherein the processor generates the
18 trajectory in real-time based on a partial fraction expansion that defines behavior
19 of the dynamic system.

20

21 39. An apparatus which controls a dynamic system in accordance with a variation in a
22 system variable, the apparatus comprising:

23 a memory which stores a position-velocity table and computer-
24 executable process steps; and

25 a processor which executes the process steps stored in the memory
26 so as (i) generate a plurality of trajectories defining velocity in terms of
27 position, the plurality of trajectories being generated in accordance with at
28 least one system variable, (ii) to store the plurality of trajectories in the
29 position-velocity table, (iii) to detect a value of the at least one system
30 variable, and (iv) to control the dynamic system in accordance with both

1 the detected value of the system variable and the trajectories stored in the
2 position-velocity table.

3

4 40. An apparatus according to Claim 39, wherein the position-velocity table
5 comprises a series of trajectories corresponding to various component movement
6 distances; and

7 wherein the processor controls a component of the dynamic system
8 by selecting one of the trajectories from the position-velocity table based
9 on the detected value of the system variable and by controlling the
10 component in accordance with the selected trajectory.

11

12 41. An apparatus according to Claim 39, wherein the processor controls a component
13 of the dynamic system by generating a function based on the plurality of
14 trajectories and the system variable, by determining a single trajectory for the
15 component based on the function, and by controlling the component based on the
16 single trajectory.

17

18 42. An apparatus according to Claim 39, wherein the processor generates the plurality
19 of trajectories by (i) estimating system parameters, the system parameters relating
20 to movement of a component of the dynamic system, (ii) determining whether the
21 system parameters have varied from predetermined system parameters, (iii)
22 modifying the trajectories based on determined system parameter variations, and
23 (iv) storing the modified trajectories in the position-velocity table.

24

25 43. An apparatus for generating a trajectory for inclusion in a position-velocity table
26 which is used in controlling a dynamic system, the apparatus comprising:

27 a memory which stores the position-velocity table and computer-
28 executable process steps; and

29 a processor which executes the process steps stored in the memory
30 so as (i) to generate a trajectory for the system, (ii) to store the trajectory

1 in the position-velocity table, and (iii) to control the system in accordance
2 with the trajectory stored in the position-velocity table;

3 wherein the processor generates the trajectory in accordance with a
4 technique for reducing unwanted vibrations in the system.

5

6 44. An apparatus according to Claim 43, wherein the apparatus controls a component
7 of the dynamic system, the component comprising a head of a data storage device;
8 and

9 wherein the processor controls the head to move to among various
10 tracks of a magnetic disk in the disk drive.

11

12 45. An apparatus according to Claim 44, wherein the technique for reducing
13 unwanted vibrations of the component comprises generating the trajectory by
14 taking into account both a system vibration limiting constraint and a system
15 sensitivity constraint.

16

17 46. An apparatus according to Claim 45, wherein the system vibration limiting and
18 sensitivity constraints reduce vibration during movement of the component by
19 less than 100%.

20

21 47. An apparatus according to Claim 44, wherein the technique for reducing
22 unwanted vibrations of the component comprises generating the trajectory by
23 taking into account one or more constraints which are a function of a movement
24 distance of the component.

25

26 48. An apparatus according to Claim 45, wherein the technique for reducing
27 unwanted vibrations of the component comprises generating the trajectory by
28 taking into account a system vibration limiting constraint only.

29

- 1 49. An apparatus according to Claim 44, wherein the technique for reducing
2 unwanted vibrations of the component comprises generating the trajectory based
3 on an input which has been shaped in accordance with a predetermined shaping
4 function.
- 5
- 6 50. An apparatus according to Claim 49, wherein the input includes both transient
7 portions and a steady state portion; and
8 wherein only the transient portions of the input have been shaped
9 in accordance with the predetermined shaping function.
- 10
- 11 51. An apparatus according to Claim 44, wherein the technique for reducing
12 unwanted vibrations of the component comprises generating the trajectory by
13 filtering a predetermined trajectory using filters having zeros which are
14 substantially near poles of the system.
- 15
- 16 52. An apparatus according to Claim 44, wherein the technique for reducing
17 unwanted vibrations of the component comprises generating the trajectory by
18 taking into account at least one of constraints relating to system thermal limits,
19 system current limits, and system duty cycle.
- 20
- 21 53. An apparatus according to Claim 44, wherein the technique for reducing
22 unwanted movement of the component comprises the steps of:
23 determining whether a trajectory excites greater than a
24 predetermined level of vibrations in the system; and
25 applying input shaping to the trajectory only in a case that the
26 trajectory excites greater than the predetermined level of vibrations.
- 27
- 28 54. An apparatus according to Claim 44, wherein the technique for reducing
29 unwanted vibrations of the component comprises generating the trajectory based
30 on a Posicast input.

- 1
- 2 55. An apparatus according to Claim 44, wherein the technique for reducing
3 unwanted vibrations of the component comprises generating the trajectory based
4 on a symmetric input.
- 5
- 6 56. An apparatus according to Claim 44, wherein the technique for reducing
7 unwanted vibrations of the component comprises generating the trajectory based
8 on a symmetric constraint that varies as a function of at least one of time and
9 component position.
- 10
- 11 57. An apparatus according to Claim 44, wherein the technique for reducing
12 unwanted vibrations of the component comprises generating a trajectory in
13 accordance with a voltage which has been controlled by controlling current.
- 14
- 15 58. An apparatus according to any one of Claims 43 to 57, wherein the processor
16 generates the trajectory by (i) identifying system parameters in real-time, and (ii)
17 modifying the trajectory in real-time in accordance with the system parameters
18 identified by the processor.
- 19
- 20 59. A method of generating a position-velocity table for a dynamic system, the
21 method comprising the steps of:
22 modeling the dynamic system in terms of partial fraction
23 expansion equations;
24 integrating the partial fraction expansion equations forward in time
25 so as to generate a trajectory for the dynamic system; and
26 storing the trajectory for the system in the position-velocity table.
- 27
- 28 60. A method according to Claim 59, wherein the partial fraction expansion equations
29 which model the dynamic system comprise:

$$\begin{aligned}
Finalpos &= \sum_{i=1}^N V_i A \Delta t \\
0 &= \sum_{i=1}^N V_i \frac{Ab}{b-a} (e^{-a(T_{end}-T_i+\Delta t)} - e^{-a(T_{end}-T_i)}) \\
0 &= \sum_{i=1}^N V_i \frac{Aa}{a-b} (e^{-b(T_{end}-T_i+\Delta t)} - e^{-b(T_{end}-T_i)}),
\end{aligned}$$

1 where Finalpos is the final position of a component of the dynamic system, T_{end}
 2 corresponds to a time at which Finalpos is reached, A, a and b are based on the
 3 system parameters, V_i are inputs to the system, T_i are the times at which V_i are
 4 input, and Δt is a time interval at which V_i are input.
 5

6 61. An apparatus according to Claim 43, wherein the position-velocity table
 7 comprises a non-dimensional position velocity table.